FORM PTO-1390 (REV. 10-2000)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		S1022/8574
		09/700617
		U S APPLICATION NO (If known, see 37 CFR 1 5)

INTERNATIONAL APPLICATION NO. PCT/SE99/790	INTERNATIONAL FILING DATE 11 May 1999 (11.05.99)	PRIORITY DATE CLAIMED 18 May 1998 (18.05.98)

TITLE OF INVENTION

IMPROVEMENTS IN, OR RELATING TO, TELECOMMUNICATIONS TRANSMISSION SYSTEMS

APPLICANT(S) FOR DO/EO/US   JOHANSSON, Magnus, OLSSON, Lennart, BAHLENBERG, Gunnar, BENGTSSON, Daniel, ISAKSSON, Mikael, OLOFSSON, Sven-Rune and ÖKVIST, Sven Göran

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.

2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.

3. ☒ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).

4. ☒ The US has been elected by the expiration of 19 months from the earliest claimed priority date (PCT Article31).

5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)).

     a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
     b. ☐ has been transmitted by the International Bureau.
     c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).

6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).

7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
     a. ☐ are attached hereto (required only if not transmitted by the International Bureau).
     b. ☐ have been communicated by the International Bureau.
     c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
     d. ☐ have not been made and will not be made.

8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(C)(5)).

Items 11. To 16. Below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. ☒ A FIRST preliminary amendment.
     ☐ A SECOND or SUBSEQUENT preliminary amendment.

14. ☐ A substitute specification.

15. ☐ A change of power of attorney and/or address letter.

16. ☒ Other items or information: Front page of PCT/SE99/00790

Express Mail Label No.   EL711221801US

Date Mailed: November 17, 2000

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U.S. APPLICATION NO (If known, see 37 C F R. 1 5)	INTERNATIONAL APPLICATION	ATTORNEY'S DOCKET NUMBER
09/700617	PCT/SE99/00790	S1022/8574

17.☐ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):

CALCULATIONS PTO USE ONLY

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1000.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $860.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but but international search fee paid to USPTO (37 CFR 1.445(a)(2)).paid to USPTO $710.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) But all claims did not satisfy provisions of PCT Article 33(1)-(4) $690.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00

ENTER APPROPRIATE BASIC FEE AMOUNT = $ 1000.00

Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 Months from the earliest claimed priority date (37 CFR 1.492(e)). $

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total Claims	42 - 20 =	22	X $18.00	$ 396.00
Independent Claims	2 - 3 =	0	X $80.00	$
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+$270.00	$
TOTAL OF ABOVE CALCULATIONS =				$

☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above ree reduced by ½. $

SUBTOTAL = $

Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 Months from the earliest claimed priority date (37 CFR 1.492(f)). $

TOTAL NATIONAL FEE = $

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate coversheet (37 CFR 3.28, 3.31). $40.00 per property + $

TOTAL FEES ENCLOSED = $ 1,396.00

Amount to be: refunded	$	
charged	$	

a. ☒ A check in the amount of $ 1,396.00 To cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ In the amount of $_____ To cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 23/2825. A duplicate of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

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SIGNATURE

MORRIS, James H.
NAME

34,681
REGISTRATION NO

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Attorney's Docket No. S1022/8574

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: S1022/8574
Serial No.: Unassigned
Filing Date: Herewith
For: IMPROVEMENTS IN, OR RELATING TO, TELECOMMUNICATIONS
 TRANSMISSION SYSTEMS

Examiner: Unassigned
Art Unit: Unassigned

Box PCT/Patent Application (DO/EO/US)
Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Sir/Madam:

Prior to examination, please amend the above-identified application as follows:

IN THE CLAIMS

1.   A receiver, for use in an OFDM transmission system, having an adaptive channel equalizer means, a sampling clock and a sampling clock control means [characterised in that] wherein ambiguity prevention means are provided to prevent said adaptive channel equalizer means from operating on time differences which should be corrected by operation of said sampling clock control means.

2.   A receiver, as claimed in claim 1, [characterised in that] wherein said sampling clock is controlled by data derived from an equalized data stream.

3.   A receiver, as claimed in [either] claim 1, [or claim 2, characterised in that] wherein sampling time deviations in said OFDM system cause received frame argument functions

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to have a linear slope and in that said sampling clock is controlled using an estimate of said frame argument functions' slope.

4.   A receiver, as claimed in [any previous claim, characterised in that] <u>claim 1,</u> <u>wherein</u> said adaptive channel equalizer is prevented from operating on said time differences by forcing the slope of a linear part of an equalizer parameter argument function to be always zero.

5.   A receiver, as claimed in claim 4, [characterised in that] <u>wherein</u> said sampling clock's frequency is controlled by a feed-back signal generated from an estimated slope of an argument function, Y.U which is the element-by-element product of an equalizer output vector U and the conjugate of a quantized vector Y derived from an output of a detector means operating on U.

6.   A receiver, as claimed in either claim 4, [or 5, characterised in that] <u>wherein</u> a slope of said equalizer parameter argument function is derived by taking an average slope of the equalizer parameter argument function by unwrapping said equalizer parameter argument function and deriving said average slope from said unwrapped equalizer parameter argument function.

7.   A receiver, as claimed in claim 6, [characterised in that] <u>wherein</u> the average slope α_k of the linear part of the equalizer parameter argument function is calculated from:

$$\alpha_k = \frac{1}{N} \sum_n \frac{\angle EQ_{n,k}}{n} \qquad (1a)$$

where $\angle EQ$ is [the] <u>an</u> unwrapped equalizer parameter argument function, n is [the] <u>a</u> carrier index, k is the frame number and N is the size of the frequency domain frame.

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8.   A receiver, as claimed in claim 6, [characterised in that] <u>wherein</u> the average slope ak of the linear part of the equalizer parameter argument function is calculated from:

$$\alpha_k = \frac{2}{n_2 - n_0} (\sum_{n=n_1=1}^{n_2} \angle EQn,k - \sum_{n=n_0}^{n_1} \angle EQ_{n,k}) \tag{1b}$$

where $\angle EQ$ is [the] <u>an</u> unwrapped equalizer parameter argument function, n is [the] <u>a</u> carrier index, k is [the] <u>a</u> frame number, N is [the] <u>a</u> size of [the] <u>a</u> frequency domain frame, n, divides [the] <u>a</u> received frequency band into two equal parts and n_0, and n_2 are lower and upper limits, respectively, of the frequency band.

9.   A receiver, as claimed in claim 8, [characterised in that] <u>wherein</u>, where several separate frequency bands are present in the received signal, equation 1(b) is applied to each frequency band separately and the average of the results employed as the slope of the equalizer parameter argument function.

10.   A receiver, as claimed in [any of claims 5 to 9, characterised in that] <u>claim 5,</u> <u>wherein</u> said equalizer parameter argument function is rotated in small steps until said slope is zero.

11.   A receiver, as claimed in [claim 12, characterised in that] <u>claim 10, wherein</u> said rotation is performed by using a vector L of complex numbers with unit magnitude and a linear argument function with a slope equal to a small fraction α_k, and in that L is calculated from:

$$L_{n,k} = \exp(-j.\beta.\frac{n}{N}.\alpha_k) \tag{2}$$

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where β controls the speed of [adaption] adaptation to the zero slope.

12.   A receiver, as claimed in [any of claims 5 to 11, characterised in that] claim 5, wherein an equaliser parameter vector EQ is adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = \left[EQ_{n,k} + \mu_1 . \frac{X^\bullet_{n,k}}{\left| X_{n,k} \right|^2} .(Y_{n,k} - U_{n,k}) \right] . L_{n,k} \quad (3a)$$

13.   A receiver, as claimed in [any of claims 5 to 11, characterised in that] claim 5, wherein an equaliser parameter vector EQ is adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = \left[EQ_{n,k} + \mu_2 . \frac{X^\bullet_{n,k}}{\left| X_{n,k} \right|} .(Y_{n,k} - U_{n,k}) \right] . L_{n,k} \quad (3b)$$

14.   A receiver, as claimed in [any of claims 5 to 11, characterised in that] claim 5, wherein an equaliser parameter vector EQ is adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = \left[EQ_{n,k} + \mu_3 . X^\bullet_{n,k} .(Y_{n,k}) \right] L_{n,k} \quad (3c)$$

15.   A receiver, as claimed in claim 12, [characterised in that] wherein the algorithm defined by equation 3(a) is employed during a start up sequence for said receiver.

16.   A receiver, as claimed in [claim 13 and/or 15, characterised in that] claim 13, wherein the algorithm defined by equation 3(c) is used for tracking slow changes in the adaptive equaliser parameter EQ subsequent to a start up sequence for said receiver.

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17.   A receiver, as claimed in [any previous claim, characterised in that] claim 1, wherein said OFDM system employs DMT.

18.   A receiver, as claimed in [any previous claim, characterised in that] claim 1, wherein said OFDM system is an ADSL system.

19.   A receiver, as claimed in [any of claims 1 to 17, characterised in that] claim 1, wherein said OFDM system is a VDSL system.

20.   A receiver, as claimed in [any of claims 1 to 17, characterised in that] claim 1, wherein said OFDM system is a mobile telecommunications system.

21.   An OFDM multi-carrier transmission system having at least one transmitter and a plurality of receivers, [characterised in that] wherein said receivers are receivers as claimed in any of claims 1 to 20.

22.   A transceiver, for use in an OFDM transmission system, [characterised in that] wherein said transceiver includes a receiver as claimed in [any of claims 1 to 20] claim 1.

23.   In an OFDM transmission system having a transmitter and a receiver, said receiver having an adaptive channel equalizer means, a sampling clock and a sampling clock control means, and said transmitter having a sampling clock, a method of maintaining synchronisation between said receiver sampling clock and said transmitter sampling clock, [characterised by preventing] wherein said adaptive channel equalizer means from operating on time differences which should be corrected by operation of said sampling clock control means.

24.   A method, as claimed in claim 23, [characterised by] comprising controlling said sampling clock with data derived from an equalized data stream.

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25.   A method, as claimed [in either] claim 23, [or claim 24. characterised by] comprising sampling time deviations in said OFDM system causing received frame argument functions to have a linear slope and by controlling said sampling clock using an estimate of said frame argument functions' slope.

26.   A method, as claimed in [any of claims 2-3 to 25, characterised by] claim 23, comprising preventing said adaptive channel equalizer from operating on said time differences by forcing the slope of a linear part of an equalizer parameter argument function to be always zero.

27.   A method, as claimed in claim 26, [characterised] comprising by controlling said sampling clock's frequency with a feed-back signal generated from an estimated slope of an argument function, Y*.U which is the element-by-element product of an equalizer output vector U and the conjugate of a quantized vector Y derived from an output of a detector means operating on U.

28,   A method, as claimed in [either claim 26, or 27, characterised by] claim 26, comprising deriving a slope of said equalizer parameter argument function by taking an average slope of the equalizer parameter argument function by unwrapping said equalizer parameter argument function and deriving said average slope torn said unwrapped equalizer parameter argument function.

29.   A method, as claimed in claim 28, [characterised by] comprising calculating the average slope α_k of the linear part of the equalizer parameter argument function from:

$$\alpha_k = \frac{1}{N}\sum_n \frac{\angle EQ_{n,k}}{n} \qquad (1a)$$

where is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number and N is the size of the frequency domain frame.

30.   A method, as claimed in claim 28, [characterised by] comprising calculating the average slope α_k of the linear part of the equalizer parameter argument function from:

$$\alpha_k = \frac{2}{n_2 - n_0} (\sum_{n=n_1=1}^{n_2} \angle EQn,k - \sum_{n=n_0}^{n_1} \angle EQ_{n,k}) \qquad (1b)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is he frame number N is the size of the frequency domain frame, n, divides the received frequency band into two equal parts and n_0 and n_2 are lower and upper limits, respectively, of the frequency band.

31.   A method, as claimed in claim 30, [characterised by] comprising, where several separate frequency bands are present in the received signal, applying equation 1 (b) to each frequency band separately and the average of the results employed as the slope of the equalizer parameter argument function.

32.   A method, as claimed in [any of claims 27 to 31, characterised by] claim 27, comprising rotating said equalizer parameter argument function in small steps until said slope is zero.

33.   A method. as claimed in claim 32, [characterised by] comprising performing said rotation by using a vector L of complex numbers with unit magnitude and a linear argument function with a slope equal to a small fraction a, and in that L is calculated from:

$$L_{n,k} = \exp(-j.\beta.\frac{n}{N}.\alpha_k) \qquad (2)$$

where β controls the speed of [adaption] adaptation to the zero slope.

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34.   A method, as claimed in [any of claims 27 to 33, characterised by] <u>claim 27,</u> <u>comprising</u> adaptively updating an equaliser parameter vector EQ using an algorithm defined by:

$$EQ_{n,k+1} = \left[EQ_{n,k} + \mu_1 \cdot \frac{X^{\bullet}_{n,k}}{\left|X_{n,k}\right|^2} \cdot (Y_{n,k} - U_{n,k}) \right] . L_{n,k} \quad (3a)$$

35.   A method, as claimed in [any of claims 27 to 33, characterised by] <u>claim 27,</u> <u>comprising</u> adaptively updating an equaliser parameter vector EQ using an algorithm defined by:

$$EQ_{n,k+1} = \left[EQ_{n,k} + \mu_2 \cdot \frac{X^{\bullet}_{n,k}}{\left|X_{n,k}\right|} \cdot (Y_{n,k} - U_{n,k}) \right] . L_{n,k} \quad (3b)$$

36.   A method, as claimed in [any of claims 27 to 33, characterised by] <u>claim 27,</u> <u>comprising</u> adaptively updating an equaliser parameter vector EQ using an algorithm defined by:

$$EQ_{n,k+1} = \left[EQ_{n,k} + \mu_3 . X^{\bullet}_{n,k} . (Y_{n,k}) \right] L_{n,k} \quad (3c)$$

37.   A method, as claimed in claim 34, [characterised] <u>comprising</u> by employing the algorithm defined by equation 3(a) during a start up sequence for said receiver.

38.   A method, as claimed in claim 34 [and for 37, characterised by] <u>comprising</u> using the algorithm defined by equation 3(c) for tracking slow changes in the adaptive equaliser parameter EQ subsequent to a tat up sequence for said receiver.

39.A method, as claimed in [any of claims 23 to 38, characterised by] <u>claim 23, wherein</u> said OFDM system employing DMT.

40.   A method, as claimed in [any of claims 23 to 38. characterised by] <u>claim 23,</u> <u>wherein</u> said OFDM system being an ADSL system.

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41.   A method, as claimed in [any of claims 23 to 33, characterised by] claim 23, wherein said OFDM system being a VDSL system.
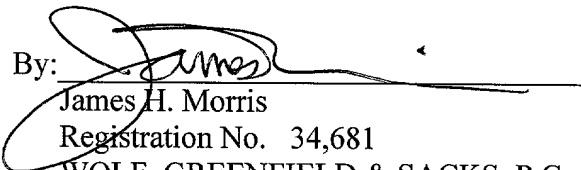

42.   A method, as claimed [in any of claims 23 to 38, characterised by] claim 23, wherein said QFDM system [being] is a mobile telecommunications system.

REMARKS

This is a preliminary amendment in which the claims have been amended to place them in better fo before initial examination by the Examiner. Favorable action is hereby earnestly solicited.

Respectfully submitted,

By: _____
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Attorney's Docket No. S1022/8574
Dated: November 17, 2000

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Improvements in, or Relating to, Telecommunications Transmission Systems

The present invention relates to multi-carrier telecommunications transmission systems employing OFDM (Orthogonal Frequency Division Multiplexing), receivers for us in multi-carrier telecommunications transmission systems, and methods of maintaining sampling clock synchronisation between a transmitter sampling clock and a receiver sampling clock in multi-carrier telecommunications transmission systems.

In a multi-carrier system of the OFDM type, including DMT (Discrete Multi-Tone), the control of a receiver's sampling clock and the updating of the equalizer's parameters may, in some cases, interfere. The present invention coordinates the equalizer's function and control of the sampling clock, in a new way, such that this problem is eliminated.

In a multi-carrier system employing OFDM, for example DMT, an adaptive channel equalizer is normally used, operating in the frequency domain. The internal parameters on which such equalizers operate include, in addition to data relating to the characteristics of the channel, information that defines a time delay between the transmitter and receiver sampling clock. The sampling clock is controlled so that the time delay between the transmitter and the receiver is effectively eliminated. If the information used to control the sampling clock is received from the equalized data stream, it will introduce an ambiguity between the operation of the channel equalizer and the mechanism used to control the sampling clock. In particular, it will not be clear to what extent the time delays between the transmitter and receiver have been eliminated by the sampling clock and/or by the equalizer. Operation of the equalizer can mask an increasing time difference, between transmitter and receiver, which the sample clock controller should be tracking. This may lead to a situation where the sampling of one frame, in the time domain, occurs at a time which is so long after the correct time period that inter symbol interference occurs. The present invention eliminates the ambiguities in the operation of the equalizer and sample clock controller by preventing the equalizer accepting time differences which should be corrected by operation of the sample clock controller. The method of the present invention incorporates a modified

algorithm for updating the equalizer's parameters.

The present invention may be used in, for example, ADSL and VDSL systems employing DMT which have relatively stationary channels. The principle, however, has general application and may be used, with advantage, in mobile and semi-mobile systems such as DECT and GSM.

According to a first aspect of the present invention, there is provided a receiver, for use in an OFDM transmission system, having an adaptive channel equalizer means, a sampling clock and a sampling clock control means characterised in that ambiguity prevention means are provided to prevent said adaptive channel equalizer means from operating on time differences which should be corrected by operation of said sampling clock control means.

Said sampling clock may be controlled by data derived from an equalized data stream.

Sampling time deviations in said OFDM system may cause received frame argument functions to have a linear slope and said sampling clock may be controlled using an estimate of said frame argument functions' slope.

Said adaptive channel equalizer may be prevented from operating on said time differences by forcing the slope of a linear part of an equalizer parameter argument function to be always zero.

Said sampling clock's frequency may be controlled by a feed-back signal generated from an estimated slope of an argument function, $Y^*.U$ which is the element-by-element product of an equalizer output vector U and the conjugate of a quantized vector Y derived from an output of a detector means operating on U.

A slope of said equalizer parameter argument function may be derived by taking an average slope of the equalizer parameter argument function by unwrapping said equalizer parameter argument function and deriving said average slope from said unwrapped equalizer parameter argument function.

The average slope α_k of the linear part of the equalizer parameter argument function may be calculated from:

$$\alpha_k = \frac{1}{N} \sum_n \frac{\angle EQ_{n,k}}{n} \qquad (1a)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number and N is the size of the frequency domain frame.

The average slope α_k of the linear part of the equalizer parameter argument function may be calculated from:

$$\alpha_k = \frac{2}{n_2 - n_0} (\sum_{n=n_1+1}^{n_2} \angle EQ_{n,k} - \sum_{n=n_0}^{n_1} \angle EQ_{n,k}) \qquad (1b)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number, N is the size of the frequency domain frame, n_1 divides the received frequency band into two equal parts and n_0 and n_2 are lower and upper limits, respectively, of the frequency band.

Where several separate frequency bands are present in the received signal, equation 1(b) may be applied to each frequency band separately and the average of the results employed as the slope of the equalizer parameter argument function.

Said equalizer parameter argument function may be rotated in small steps until said slope is zero.

Said rotation may be performed by using a vector L of complex numbers with unit magnitude and a linear argument function with a slope equal to a small fraction α_k, and in that L is calculated from:

$$L_{n,k} = \exp(-j . \beta . \frac{n}{N} . \alpha_k) \qquad (2)$$

where β controls the speed of adaption to the zero slope.

An equaliser parameter vector EQ may be adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_1 \cdot \frac{X^{*}_{n,k}}{|X_{n,k}|^2} \cdot (Y_{n,k} - U_{n,k})] \cdot L_{n,k} \qquad (3a)$$

An equaliser parameter vector EQ may be adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_2 \cdot \frac{X^{*}_{n,k}}{|X_{n,k}|} \cdot (Y_{n,k} - U_{n,k})] \cdot L_{n,k} \qquad (3b)$$

An equaliser parameter vector EQ may be adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_3 \cdot X^{*}_{n,k} \cdot (Y_{n,k} - U_{n,k})] \cdot L_{n,k} \qquad (3c)$$

The algorithm defined by equation 3(a) may be employed during a start up sequence for said receiver.

The algorithm defined by equation 3(c) may be used for tracking slow changes in the adaptive equaliser parameter EQ subsequent to a start up sequence for said receiver.

Said OFDM system may employ DMT.

Said OFDM system may be an ADSL system.

Said OFDM system may be a VDSL system.

Said OFDM system may be a mobile telecommunications system.

According to a second aspect of the present invention, there is provided an OFDM multi-carrier transmission system having at least one transmitter and a plurality of receivers, characterised in that said receivers are receivers as set forth in any preceding paragraph.

According to a third aspect of the present invention, there is provided a transceiver, for use in an OFDM transmission system, characterised in that said transceiver includes a receiver as set forth in any preceding paragraph.

According to a fourth aspect of the present invention, there is provided, in an OFDM transmission system having a transmitter and a receiver, said receiver having an adaptive channel equalizer means, a sampling clock and a sampling clock control means, and said transmitter having a sampling clock, a method of maintaining synchronisation between said receiver sampling clock and said transmitter sampling clock, characterised by preventing said adaptive channel equalizer means from operating on time differences which should be corrected by operation of said sampling clock control means.

Said sampling clock may be controlled by data derived from an equalized data stream.

Sampling time deviations in said OFDM system may cause received frame argument functions to have a linear slope and said sampling clock may be controlled using an estimate of said frame argument functions' slope.

Said adaptive channel equalizer may be prevented from operating on said time differences by forcing the slope of a linear part of an equalizer parameter argument function to be always zero.

Said sampling clock's frequency may be controlled by a feed-back signal generated from an estimated slope of an argument function, $Y^*.U$ which is the element-by-element product of an equalizer output vector U and the conjugate of a quantized vector Y derived from an output of a detector means operating on U

A slope of said equalizer parameter argument function may be derived by taking an average slope of the equalizer parameter argument function by unwrapping said equalizer parameter argument function and deriving said average slope from said unwrapped equalizer parameter argument function.

The average slope α_k of the linear part of the equalizer parameter argument function may be calculated from:

$$\alpha_k = \frac{1}{N}\sum_n \frac{\angle EQ_{n,k}}{n} \qquad (1a)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number and N is the size of the frequency domain frame.

The average slope α_k of the linear part of the equalizer parameter argument function may be calculated from:

$$\alpha_k = \frac{2}{n_2-n_0}(\sum_{n=n_1+1}^{n_2} \angle EQ_{n,k} - \sum_{n=n_0}^{n_1} \angle EQ_{n,k}) \qquad (1b)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number, N is the size of the frequency domain frame, n_1 divides the received frequency band into two equal parts and n_0 and n_2 are lower and upper limits, respectively, of the frequency band.

Where several separate frequency bands are present in the received signal, equation 1(b) may be applied to each frequency band separately and the average of the results employed as the slope of the equalizer parameter argument function.

Said equalizer parameter argument function may be rotated in small steps until said slope is zero.

Said rotation may be performed by using a vector L of complex numbers with unit magnitude and a linear argument function with a slope equal to a small

fraction α_k, and in that L is calculated from:

$$L_{n,k} = \exp(-j.\beta.\frac{n}{N}.\alpha_k) \qquad (2)$$

where β controls the speed of adaption to the zero slope.

An equaliser parameter vector EQ may be adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_1.\frac{X^*_{n,k}}{|X_{n,k}|^2}.(Y_{n,k} - U_{n,k})].L_{n,k} \qquad (3a)$$

An equaliser parameter vector EQ may be adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_2.\frac{X^*_{n,k}}{|X_{n,k}|}.(Y_{n,k} - U_{n,k})].L_{n,k} \qquad (3b)$$

An equaliser parameter vector EQ may be adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_3.X^*_{n,k}.(Y_{n,k} - U_{n,k})].L_{n,k} \qquad (3c)$$

The algorithm defined by equation 3(a) may be employed during a start up sequence for said receiver.

The algorithm defined by equation 3(c) may be used for tracking slow changes in the adaptive equaliser parameter EQ subsequent to a start up sequence for said receiver.

Said OFDM system may employ DMT.

Said OFDM system may be an ADSL system.

Said OFDM system may be a VDSL system.

Said OFDM system may be a mobile telecommunications system.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 illustrates, in block schematic form, the equalizer and sampling clock control unit of a receiver according to the present invention.

Figure 2 illustrates the time domain data format for OFDM.

In a multi-carrier system employing OFDM, for example DMT, an adaptive channel equalizer is normally used, operating in the frequency domain. The equalizer operates on, inter alia, parameters which define the time delay between the transmitter and receiver sampling clocks. The sampling clock, however, must be controlled so that the time delay between the transmitter and the receiver is effectively eliminated. If the information used to control the sampling clock is received from the equalized data stream, there will be an ambiguity between the operation of the channel equalizer and the sampling clock control mechanism. In particular, it will not be clear to what extent time delays between the transmitter and receiver have been eliminated by operation of the sampling clock control mechanism, or the equaliser. Operation of the equalizer can thus mask an increasing time difference, between transmitter and receiver, which the sample clock controller should track. This can lead to a situation where the sampling of one frame, in the time domain, occurs at a time, which is so long after the correct time period, that inter symbol interference occurs. The present invention eliminates the ambiguities in the operation of the equaliser and sample clock controller by preventing the equalizer accepting time differences which should be corrected by operation of the sample clock controller.

A sampling time deviation in an OFDM system causes the received frame argument function to have a linear slope. The sampling clock oscillator is.

therefore, controlled using an estimate of this slope. The estimation of the argument function is performed using equalized data. Since the equalizer adapts to the channel properties, it also eliminates any sampling time deviations. This means that the equalizer and the sampling clock control may mutually cancel each other out, in respect of sampling time deviations. Since the frame timing is set during the start-up sequence, it also relies on these control actions. It is, therefore, necessary to prevent such mutual cancellation.

The method of the present invention solves the mutual cancellation problem by preventing the equalizer from operating on the time delay. This means that the slope of the linear part of the equalizer parameter argument function is always substantially zero. An adaptive parameter estimation algorithm that fulfils this requirement is incorporated in the present invention.

Figure 1 illustrates an OFDM receiver, according to the present invention. Incoming frequency domain data, X, passes to an equalizer and then, as an equalized signal, to a detector, i.e. a quantizer. The output from the detector is passed to a symbol detector from which a decoded data stream emerges. Frame start pulses, in the time domain, are derived from a frame timing algorithm which operates on the received frequency domain input data and runs in a frame timing mechanism. The equalizer is controlled by an equalisation parameter updating algorithm which operates on the frequency domain input data and an output derived from the sampling clock control algorithm. The equaliser is controlled by signal EQ. The sampling clock control algorithm, which operates in the sampling clock control mechanism, produces a signal for controlling the sampling clock oscillator

The frequency-domain data is the Fourier transform of the received time-domain OFDM frames. The time-domain frames are sampled in synchronism with the transmitter so that each received frame contains data from only one transmitted frame. This is important in order to maintain the orthogonality of the frames.

A common time-domain format for the transmission of OFDM frames, is illustrated in Figure 2, where CE = Cyclic Extension.

The signalling interval contains a cyclic extension and a frame. The cyclic

extension is a copy of the opposite part of the frame. This means that a frame sampled anywhere inside the signalling interval will contain data from one transmitted frame only, in the correct order. A deviation from the exact frame timing leads to a cyclic permutation of the frame, but the orthogonality is still maintained. The cyclic extension may be split into two parts, namely a prefix part and a suffix part.

A training procedure is required at start-up. The frame timing is adjusted until the received frames are sampled within the frame interval. The sampling clock frequency must also be adjusted so that it is sufficiently close to the transmitter clock frequency to enable the equalizer to estimate a fairly stable set of parameters.

The generation of frame start pulses is achieved by counting sampling clock intervals. Therefore, after the initial setting of the sampling clock timing during the training procedure, maintenance of synchronisation between a receiver and a transmitter will be dependent on the feed-back control of the sampling clock oscillator. The clock oscillator frequency is controlled by a feed-back signal generated from the estimated slope of the argument function of vector Y*U; which is the element-by-element product of the conjugate of the quantized vector Y and the equalizer output vector U.

After the training procedure the equalizer parameters EQ will represent the complex frequency-domain inverse of the channel. The product vector Y*U will then have a linear argument function with a slope representing the time deviation between the transmitter and receiver sample timing. However, the argument function of EQ may also have a linear part with non-zero slope unless measures are taken to prevent this occurring. This also corresponds to a deviation between the transmitter and receiver sample timing. Since the vector EQ represents the inverse channel, the slope of EQ has the opposite sign to the slope of Y*U for the same time deviation. Therefore, they may become large and still cancel each other out. This is a potential problem, since the frame timing can gradually drift away from the frame interval and inter-symbol interference will eventually increase.

The solution to this problem, proposed by the present invention, is to

prevent the equalizer parameter vector EQ from representing time delay. This means that the linear part of its argument function must be forced to zero slope The sample time deviation will then be represented by the argument function slope of Y·U and taken care of by the sampling clock oscillator feed-back controller.

The equalizer parameter estimation is performed adaptively using, as input data, the frequency-domain vectors X, U and Y, see Figure 1. During the first part of the start-up sequence, the vector Y is temporarily replaced by a training frame T with known content. In the equations, set out in this patent specification, k is the frame number, n is the carrier index and N is the size of the frequency-domain frame.

The novel feature of the algorithm employed by the present invention is that any non-zero time delay representation included in the equalizer parameter vector EQ will be eliminated.

The exact linear argument function representing the time delay is not available, but an approximation can be estimated. The argument function of the equalizer parameter vector is generally non-linear, but a linear part can be found by taking the average slope of the argument function. This means that the unwrapped argument function has to be calculated and the average slope of this used as a measure of the time delay. Thus, the algorithm will use this as a feed-back value to successively rotate the argument function in small steps until the average slope is zero.

The argument function of the equalizer parameters is the vector of arguments of the individual complex elements. The argument of a complex number is the inverse tangent of the imaginary part divided by the real part. A problem involved in this calculation is that the inverse tangent function is periodic with a period 2π radians. In this application it is necessary to handle larger arguments than π radians, which is the range of the inverse tangent function. An assumption used here is that the difference in argument between adjacent parameters is smaller than π radians. It is then possible to compensate for each discontinuity due to the inverse tangent function periodicity and thus unwrap the argument function.

The average slope α_k of the linear part can be calculated as shown in Equation (1a), or by some other standard method, using the unwrapped argument function of EQ.

$$\alpha_k = \frac{1}{N}\sum_n \frac{\angle EQ_{n,k}}{n} \qquad (1a)$$

If the lowest frequency carriers are not present in the frame, it is not possible to find the true argument function since there will be an unknown starting value for the available part of the function. This is not a problem in the present application, since the average slope can still be calculated.

Equation (1b) shows an alternative algorithm that gives the average slope of a contiguous band of active carriers.

$$\alpha_k = \frac{2}{n_2 - n_0}\left(\sum_{n=n_1+1}^{n_2} \angle EQ_{n,k} - \sum_{n=n_0}^{n_1} \angle EQ_{n,k}\right) \qquad (1b)$$

Indexes n_0 and n_2 are the lower and upper limits respectively of the band. Index n_1 divides the band into two equal parts. If several separate bands are used, equation (1b) is applied to each band and the average of the results is calculated. The algorithm according to equation (1b) gives a very simple hardware implementation.

The rotation operation is performed using a vector L of complex numbers with unit magnitude and a linear argument function with a slope equal to a small fraction of α_k. The vector L is calculated using Equation (2).

$$L_{n,k} = \exp\left(-j.\beta.\frac{n}{N}.\alpha_k\right) \qquad (2)$$

The coefficient β controls the speed of adaption to the zero average slope of the *EQ* vector argument function.

Different algorithms for the adaptive updating of the equalizer parameter vector EQ are given by Equations (3a), (3b) and (3c). They all include the new feature to eliminate the time delay representation. One specific feature that characterises the present invention is the multiplication by the rotational vector L.

5 The algorithm according to Equation (3a) is the fastest approach, while Equation (3c), which is a modified LMS algorithm, has the best performance for low SNR. The selection is not obvious, but Equation (3a) can be used during part of the start-up sequence and Equation (3c) can be used for the tracking of subsequent slow changes.

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_1 \cdot \frac{X^*_{n,k}}{|X_{n,k}|^2} \cdot (Y_{n,k} - U_{n,k})] . L_{n,k} \qquad (3a)$$

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_2 \cdot \frac{X^*_{n,k}}{|X_{n,k}|} \cdot (Y_{n,k} - U_{n,k})] . L_{n,k} \qquad (3b)$$

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_3 \cdot X^*_{n,k} \cdot (Y_{n,k} - U_{n,k})] . L_{n,k} \qquad (3c)$$

10 The main innovation of the present invention is the principle that the equalizer should be prevented from representing time delay.

The present invention can be realised as a method of implementing this principle as a part of the equalizer parameter updating algorithm.

The sample timing control using this method is very robust in the case of
15 disturbances, since every active carrier is used in the timing deviation estimation.

CLAIMS

1. A receiver, for use in an OFDM transmission system, having an adaptive channel equalizer means, a sampling clock and a sampling clock control means characterised in that ambiguity prevention means are provided to prevent said adaptive channel equalizer means from operating on time differences which should be corrected by operation of said sampling clock control means.

2. A receiver, as claimed in claim 1, characterised in that said sampling clock is controlled by data derived from an equalized data stream.

3. A receiver, as claimed in either claim 1, or claim 2, characterised in that sampling time deviations in said OFDM system cause received frame argument functions to have a linear slope and in that said sampling clock is controlled using an estimate of said frame argument functions' slope.

4. A receiver, as claimed in any previous claim, characterised in that said adaptive channel equalizer is prevented from operating on said time differences by forcing the slope of a linear part of an equalizer parameter argument function to be always zero.

5. A receiver, as claimed in claim 4, characterised in that said sampling clock's frequency is controlled by a feed-back signal generated from an estimated slope of an argument function, $Y^*.U$ which is the element-by-element product of an equalizer output vector U and the conjugate of a quantized vector Y derived from an output of a detector means operating on U.

6. A receiver, as claimed in either claim 4, or 5, characterised in that a slope of said equalizer parameter argument function is derived by taking an average slope of the equalizer parameter argument function by unwrapping said equalizer parameter argument function and deriving said average slope from said unwrapped equalizer parameter argument function.

7. A receiver, as claimed in claim 6, characterised in that the average slope

α_k of the linear part of the equalizer parameter argument function is calculated from:

$$\alpha_k = \frac{1}{N} \sum_n \frac{\angle EQ_{n,k}}{n} \qquad (1a)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number and N is the size of the frequency domain frame.

8.   A receiver, as claimed in claim 6, characterised in that the average slope α_k of the linear part of the equalizer parameter argument function is calculated from:

$$\alpha_k = \frac{2}{n_2 - n_0} \left(\sum_{n=n_1+1}^{n_2} \angle EQ_{n,k} - \sum_{n=n_0}^{n_1} \angle EQ_{n,k} \right) \qquad (1b)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number, N is the size of the frequency domain frame, n_1 divides the received frequency band into two equal parts and n_0 and n_2 are lower and upper limits, respectively, of the frequency band.

9.   A receiver, as claimed in claim 8, characterised in that, where several separate frequency bands are present in the received signal, equation 1(b) is applied to each frequency band separately and the average of the results employed as the slope of the equalizer parameter argument function.

10.   A receiver, as claimed in any of claims 5 to 9, characterised in that said equalizer parameter argument function is rotated in small steps until said slope is zero.

11.   A receiver, as claimed in claim 12, characterised in that said rotation is performed by using a vector L of complex numbers with unit magnitude and a linear argument function with a slope equal to a small fraction α_k, and in that L is calculated from:

$$L_{n,k} = \exp(-j.\beta.\frac{n}{N}.\alpha_k) \qquad (2)$$

where β controls the speed of adaption to the zero slope.

12.   A receiver, as claimed in any of claims 5 to 11, characterised in that an equaliser parameter vector EQ is adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_1 . \frac{X^*_{n,k}}{|X_{n,k}|^2} . (Y_{n,k} - U_{n,k})].L_{n,k} \qquad (3a)$$

13.   A receiver, as claimed in any of claims 5 to 11, characterised in that an equaliser parameter vector EQ is adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_2 . \frac{X^*_{n,k}}{|X_{n,k}|} . (Y_{n,k} - U_{n,k})].L_{n,k} \qquad (3b)$$

14.   A receiver, as claimed in any of claims 5 to 11, characterised in that an equaliser parameter vector EQ is adaptively updated using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_3 . X^*_{n,k} . (Y_{n,k} - U_{n,k})].L_{n,k} \qquad (3c)$$

15.   A receiver, as claimed in claim 12, characterised in that the algorithm defined by equation 3(a) is employed during a start up sequence for said receiver.

16.   A receiver, as claimed in claim 13 and/or 15, characterised in that the algorithm defined by equation 3(c) is used for tracking slow changes in the adaptive equaliser parameter EQ subsequent to a start up sequence for said receiver.

17.   A receiver, as claimed in any previous claim, characterised in that said OFDM system employs DMT.

18. A receiver, as claimed in any previous claim, characterised in that said OFDM system is an ADSL system.

19. A receiver, as claimed in any of claims 1 to 17, characterised in that said OFDM system is a VDSL system.

20. A receiver, as claimed in any of claims 1 to 17, characterised in that said OFDM system is a mobile telecommunications system.

21. An OFDM multi-carrier transmission system having at least one transmitter and a plurality of receivers, characterised in that said receivers are receivers as claimed in any of claims 1 to 20.

22. A transceiver, for use in an OFDM transmission system, characterised in that said transceiver includes a receiver as claimed in any of claims 1 to 20.

23. In an OFDM transmission system having a transmitter and a receiver, said receiver having an adaptive channel equalizer means, a sampling clock and a sampling clock control means, and said transmitter having a sampling clock, a method of maintaining synchronisation between said receiver sampling clock and said transmitter sampling clock, characterised by preventing said adaptive channel equalizer means from operating on time differences which should be corrected by operation of said sampling clock control means.

24. A method, as claimed in claim 23, characterised by controlling said sampling clock with data derived from an equalized data stream.

25. A method, as claimed in either claim 23, or claim 24, characterised by sampling time deviations in said OFDM system causing received frame argument functions to have a linear slope and by controlling said sampling clock using an estimate of said frame argument functions' slope.

26. A method, as claimed in any of claims 23 to 25, characterised by preventing said adaptive channel equalizer from operating on said time differences by forcing the slope of a linear part of an equalizer parameter argument function to be always

zero.

27.   A method, as claimed in claim 26, characterised by controlling said sampling clock's frequency with a feed-back signal generated from an estimated slope of an argument function, $Y^*.U$ which is the element-by-element product of an equalizer output vector U and the conjugate of a quantized vector Y derived from an output of a detector means operating on U.

28.   A method, as claimed in either claim 26, or 27, characterised by deriving a slope of said equalizer parameter argument function by taking an average slope of the equalizer parameter argument function by unwrapping said equalizer parameter argument function and deriving said average slope from said unwrapped equalizer parameter argument function.

29.   A method, as claimed in claim 28, characterised by calculating the average slope α_k of the linear part of the equalizer parameter argument function from:

$$\alpha_k = \frac{1}{N} \sum_n \frac{\angle EQ_{n,k}}{n} \qquad (1a)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number and N is the size of the frequency domain frame.

30.   A method, as claimed in claim 28, characterised by calculating the average slope α_k of the linear part of the equalizer parameter argument function from:

$$\alpha_k = \frac{2}{n_2 - n_0} (\sum_{n=n_1+1}^{n_2} \angle EQ_{n,k} - \sum_{n=n_0}^{n_1} \angle EQ_{n,k}) \qquad (1b)$$

where $\angle EQ$ is the unwrapped equalizer parameter argument function, n is the carrier index, k is the frame number, N is the size of the frequency domain frame, n_1 divides the received frequency band into two equal parts and n_0 and n_2 are lower and upper limits, respectively, of the frequency band.

31.   A method, as claimed in claim 30, characterised by, where several separate frequency bands are present in the received signal, applying equation 1(b) to each frequency band separately and the average of the results employed as the slope of the equalizer parameter argument function.

32.   A method, as claimed in any of claims 27 to 31, characterised by rotating said equalizer parameter argument function in small steps until said slope is zero.

33.   A method, as claimed in claim 32, characterised by performing said rotation by using a vector L of complex numbers with unit magnitude and a linear argument function with a slope equal to a small fraction α_k, and in that L is calculated from:

$$L_{n,k}=\exp(-j.\beta.\frac{n}{N}.\alpha_k) \qquad (2)$$

where β controls the speed of adaption to the zero slope.

34.   A method, as claimed in any of claims 27 to 33, characterised by adaptively updating an equaliser parameter vector EQ using an algorithm defined by:

$$EQ_{n,k+1}=[EQ_{n,k}+\mu_1.\frac{X^{\bullet}_{n,k}}{|X_{n,k}|^2}.(Y_{n,k}-U_{n,k})].L_{n,k} \qquad (3a)$$

35.   A method, as claimed in any of claims 27 to 33, characterised by adaptively updating an equaliser parameter vector EQ using an algorithm defined by:

$$EQ_{n,k+1}=[EQ_{n,k}+\mu_2.\frac{X^{\bullet}_{n,k}}{|X_{n,k}|}.(Y_{n,k}-U_{n,k})].L_{n,k} \qquad (3b)$$

36.   A method, as claimed in any of claims 27 to 33, characterised by adaptively updating an equaliser parameter vector EQ using an algorithm defined by:

$$EQ_{n,k+1} = [EQ_{n,k} + \mu_3 . X^{*}_{n,k} . (Y_{n,k} - U_{n,k})] . L_{n,k} \qquad (3c)$$

37.   A method, as claimed in claim 34, characterised by employing the algorithm defined by equation 3(a) during a start up sequence for said receiver.

38.   A method, as claimed in claim 34 and/or 37, characterised by using the algorithm defined by equation 3(c) for tracking slow changes in the adaptive equaliser parameter EQ subsequent to a start up sequence for said receiver.

39.   A method, as claimed in any of claims 23 to 38, characterised by said OFDM system employing DMT.

40.   A method, as claimed in any of claims 23 to 38, characterised by said OFDM system being an ADSL system.

41.   A method, as claimed in any of claims 23 to 38, characterised by said OFDM system being a VDSL system.

42.   A method, as claimed in any of claims 23 to 38, characterised by said OFDM system being a mobile telecommunications system.

ABSTRACT

Improvements in, or Relating to, Telecommunications
Transmission Systems

In a multi-carrier system employing OFDM, for example DMT, an adaptive channel equalizer is normally used, operating in the frequency domain. The internal parameters on which such equalizers operate information that defines a time delay between the transmitter and receiver sampling clock. The sampling clock is controlled so that the time delay between the transmitter and the receiver is effectively eliminated. If the information used to control the sampling clock is received from the equalized data stream, it will introduce an ambiguity between the operation of the channel equalizer and the mechanism used to control the sampling clock. Operation of the equalizer can mask an increasing time difference, between transmitter and receiver, which the sample clock controller should be tracking. The present invention eliminates the ambiguities in the operation of the equalizer and sample clock controller by preventing the equalizer accepting time differences which should be corrected by operation of the sample clock controller. The method of the present invention incorporates a modified algorithm for updating the equalizer's parameters.

The present invention may be used in, for example, ADSL and VDSL systems employing DMT which have relatively stationary channels. The principle, however, has general application and may be used, with advantage, in mobile and semi-mobile systems such as DECT and GSM.
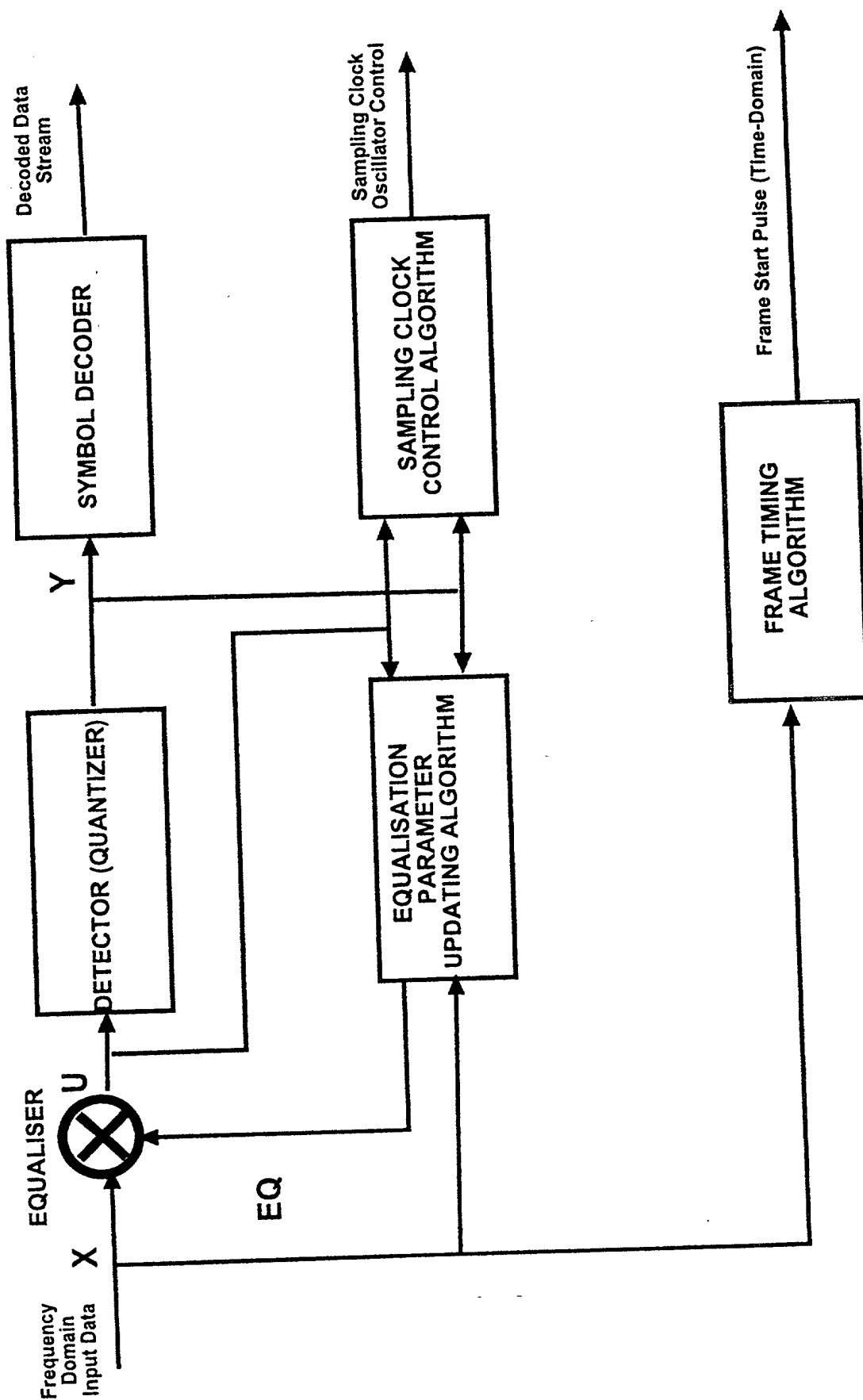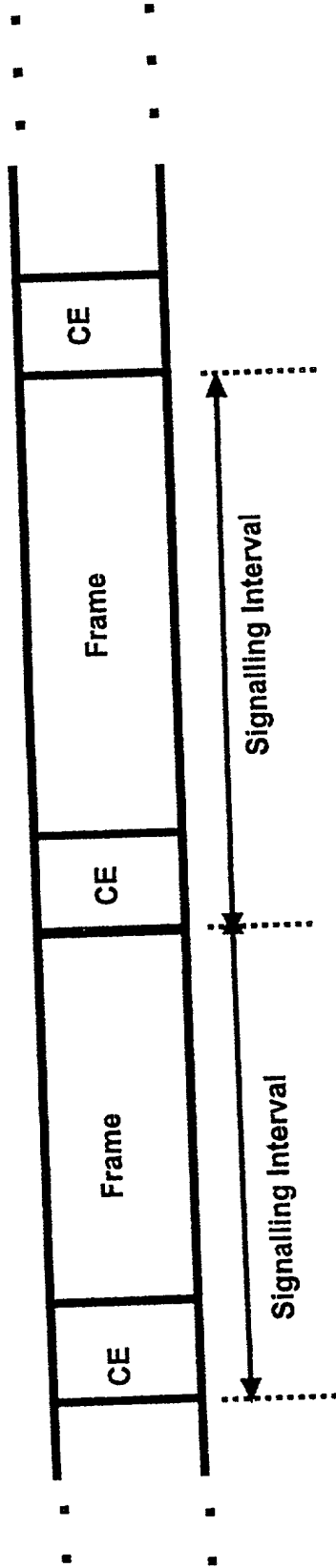
FIGURE 1

CE = Cyclic Extension

FIGURE 2

Declaration and Power of Attorney for Patent Application

Déclaration et Pouvoirs pour Demande de Brevet

French Language Declaration

En tant que l'inventeur nommé ci-après, je déclare par le présent acte que:

As a below named inventor, I hereby declare that:

Mon domicile, mon adresse postale, et ma nationalité sont ceux figurant ci-dessous à côté de mon nom.

My residence, post office address and citizenship are as stated next to my name.

Je crois être le premier inventeur original et unique (si un seul nom est mentionné ci-dessous), ou l'un des premiers co-inventeurs originaux (si plusieurs noms sont mentionnés ci-dessous) de l'objet revendiqué, pour lequel une demande de brevet a été déposée concernant l'invention intitulée:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

IMPROVEMENTS IN, OR RELATING TO, TELECOMMUNICATIONS TRANSMISSION SYSTEMS

et dont la description est fournie ci-joint à moins que la case suivante n'ait été cochée:

IMPROVEMENTS IN, OR RELATING TO, TELECOMMUNICATIONS TRANSMISSION SYSTEMS

the specification of which is attached hereto unless one of the following boxes is checked:

☐ a été déposée le_____sous le numéro de demande des Etats-Unis ou le numéro de demande international PCT
_____

☐ les specifications portant le dossier de l'avocat numero _____

et modifiée le _____
(le cas échéant).

☒ was filed on November 17, 2000 as United States Application Number 09/700617, PCT International Number PCT/SE99/00790

☒ the specification of which bears attorney docket No. S1022/8574

and was amended on _____
(if applicable).

Je déclare par le présent acte avoir passé en revue et compris le contenu de la description ci-dessus, revendications comprises, telles que modifiées par toute modification dont il aura été fait référence ci-dessus.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

Je reconnais devoir divulguer toute information pertinente à la brevetabilité, comme défini dans le Titre 37, §1.56 du Code fédéral des réglementations.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

Page 1 of 5

PTO/SB/105(Rev. 5-95) OMB 0651-0032

508255.1

French Language Declaration

Je revendique par le présent acte avoir la priorité étrangère, en vertu du Titre 35, §119(a)-(d) ou § 365(b) du Code des Etats-Unis, sur toute demande étrangère de brevet ou certificat d'inventeur ou, en vertu du Titre 35, § 365(a) du même Code, sur toute demande internationale PCT désignant au moins un pays autre que les Etats-Unis et figurant ci-dessous et, en cochant la case, j'ai aussi indiqué ci-dessous toute demande étrangère de brevet, tout cèrtificat d'inventeur ou toute demande internationale PCT ayant une date de dépôt précédant celle de la demande à propos de laquelle une priorité est revendiquée.

I hereby claim foreign priority under Title 35, United States Code, §119(a)-(d) or § 365(b) of any foreign applications(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below, and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed:

Prior foreign application(s)
Demande(s) de brevet antérieure(s)

PCT/SE99/00790	PCT
(Number)	(Country)
(Numéro)	(Pays)

981748.6	Sweden
(Number)	(Country)
(Numéro)	(Pays)

	Priority not claimed
	Droit de priorité non revendiqué
11 May 1999	□
(Day/Month/Year Filed)	
(Jour/Mois/Année de dépôt)	

18 May 1998	□
(Day/Month/Year Filed)	
(Jour/Mois/Année de dépôt)	

Je revendique par le présent acte tout bénéfice, en vertu du Titre 35 §119(e) du Code des Etats-Unis, de toute demande de brevet provisoire effectuée aux Etats-Unis et figurant ci-dessous.

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

(Application No.)	(Filing Date)
(N° de demande)	(Date de dépôt)

(Application No.)	(Filing Date)
(N° de demande)	(Date de dépôt)

Je revendique par le présent acte, le bénéfice, en vertu du Titre 35 § 120 du Code des Etats-Unis, de toute demande de brevet effectuée aux Etats-Unis, ou en vertu du Titre 35, § 365(c) du même Code, de toute demande internationale PCT désignant les Etats-Unis et figurant ci-dessous et, dans la mesure où l'objet de chacune des revendications de cette demande de brevet n'est pas divulgué dans la demande antérieure américaine ou internationale PCT, en vertu des dispositions du premier paragraphe du Titre 35, § 112 du Code des Etats-Unis, je reconnais devoir divulguer toute information pertinente à la brevetabilité, comme défini dans le Titre 37, § 1.56 du Code Fédéral des réglementations, dont j'ai pu disposer entre la date de dépôt de la demande antérieure et la date de dépôt de la demande nationale ou internationale PCT de la présente demande:

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or § 365(c) of any PCT international application(s) designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application No.)	(Filing Date)
(N° de Demande)	(Date de Dépôt)

(Application No.)	(Filing Date)
(N° de Demande)	(Date de Dépôt)

(Status)(Patented, pending abandoned)
(Statut)(breveté, en cours d'examen, abandonné)

(Status)(Patented, pending abandoned)
(Statut)(breveté, en cours d'examen, abandonné)

Je déclare par le présent acte que toute déclaration ci-incluse est, à ma connaissance, véridique et que toute déclaration formulée à partir de renseignements ou de suppositions est tenue pour véridique; et de plus, que toutes ces déclarations ont été formulées en sachant que toute fausse déclaration volontaire ou son équivalent est passible d'une amende ou d'une incarcération, ou des deux, en vertu de la Section 1001 du Titre 18 du Code des Etats-Unis, et que de telles déclarations volontairement fausses risquent de compromettre la validité de la demande de brevet ou du brevet délivré à partir de celle-ci.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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POUVOIR: En tant que l'inventeur cité, je désigne par la présente l'(les) avocat(s) et/ou agent(s) suivant(s) pour qu''il(s) poursuive(nt) la procédure de cette demande de brevet et traite(nt) toute affaire s'y rapportant avec l'Office des brevets et des marques: *(mentionner le nom et le numéro d'enregistrement).*

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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Lawrence M. Green	29,384	Richard F. Giunta	36,149	Robert M. Abrahamsen	37,482	Robert H. Walat	46,324
Steven J. Henry	27,900	Douglas R. Wolf	36,971	Edward J. Russavage	43,069	Thomas G. Field	45,596
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Therese A. Hendricks	30,389	Timothy J. Oyer	36,628	Neil P. Ferraro	39,188	M. Brad Lawrence	P-47,210
William R. McClellan	29,409	John N. Anastasi	37,765	Lisa E. Winsor	44,405	Theodore E. Galanthay	24,122
Ronald J. Krandsdorf	20,004	Helen C. Lockhart	39,248	Mark Steinberg	40,829	Lisa K. Jorgenson	34,845
M. Lawrence Oliverio	30,915	James M. Hanifin, Jr.	37,929	Stephen R. Finch	42,534	Robert D McCutcheon	38,717
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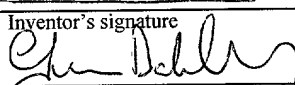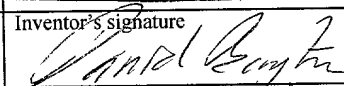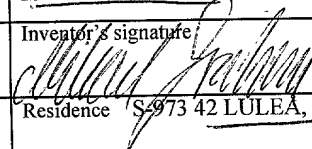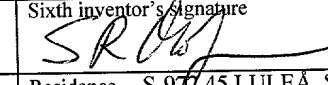| Adresser toute correspondance à:	Send correspondence to: James H. Morris Wolf, Greenfield & Sacks, P.C, Federal Reserve Plaza 600 Atlantic Avenue, Boston, MA 02210-2211(USA)
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Signature de l'inventeur Date	Inventor's signature Date
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Nom complet du septième co-inventor, le cas échéant	Full name of seventh joint inventor, if any
7-00	ÖKVIST, Sven-Göran
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